A METHOD OF DETERMINING TIMING CLEARANCE FROM A POSITION AND AN ELECTRICAL CHARACTERISTIC

The present invention relates to a method of determining clearance between two moving parts.

The method of the invention is more particularly usable in engines including valves each associated with a respective valve actuator, and it serves to determine the clearance that exists between the stem of each valve and the moving member of the actuator that co-operates with the valve stem in order to move the valve between an open position in which the valve is spaced apart from its seat, and a closed position in which the valve is pressed against its seat.

Electromagnetic valve actuators exist that comprise, in conventional manner, both resilient means and electromagnetic means for actuating the moving member between two extreme positions corresponding respectively to the open position of the valve and to the closed position of the valve. The resilient means generally comprise a spring associated with the moving member to return it elastically into its extreme open position, and a spring associated with the valve stem in order to return it elastically into its closed position so as to urge the moving member elastically into its extreme closed position. The electromagnetic means generally comprise an electromagnet for bringing and/or holding the moving member in its extreme open position, and an electromagnet for bringing and/or holding the moving member in its extreme closed position.

In order to be certain that the valve is properly pressed against its seat when the moving member is in its extreme closed position, the moving member and the valve are not connected to each other, and clearance commonly referred to as "timing clearance" is provided between the moving member and the valve when the moving member is in its extreme closed position and the valve is properly

pressed against its seat by the spring which is associated therewith.

Under such circumstances, if the moving member is brought quickly from the extreme closed position to the extreme open position, the moving member will strike the valve stem. This impact, which in any event is noisy, leads to mechanical stresses and wear of the moving member and of the valve stem that can, in extreme cases, lead to damage thereof. It is therefore important to know precisely the amount of timing clearance that exists so that the electromagnetic means can be controlled firstly to bring the moving member gently into contact with the valve stem, and then to accelerate the moving member once it is pressing against the valve stem.

Unfortunately, timing clearance varies while the engine is in operation, in particular as a function of temperature, and also over the lifetime of the engine, in particular as a function of the wear of the valve and of the various components of the valve actuator. In addition, timing clearance can vary from one actuator to another as a function of their manufacturing tolerances.

In order to determine the timing clearance, a method is known that consists in controlling the actuator means to move the moving member from the extreme closed position to the extreme open position and to detect variation in an electrical characteristic in the electromagnetic actuator means. This variation in the electrical characteristic is caused by the increase in the opposition to movement of the moving member once it encounters the valve stem. The timing clearance is then determined by measuring the time that elapses between the beginning of the moving member being set into motion and the appearance of the variation in the electrical characteristic. Nevertheless, determining timing clearance in that way turns out to be relatively inaccurate.

An object of the invention is to provide means enabling timing clearance to be determined simply and accurately.

To this end, the invention provides a method of determining clearance between a stem of a valve in an engine and a moving member of an electromagnetic actuator comprising electromagnetic displacement means for moving the moving member between an extreme open position and an extreme closed position of the valve, the electromagnetic displacement means being controlled by servo-control means on the basis of a reference electrical characteristic. The method comprises the steps of:

- controlling the electromagnetic means to obtain a displacement speed that is substantially constant for the moving member between the extreme closed position and the extreme open position;
- obtaining values of the reference electrical characteristic for intermediate positions of the moving member; and
- detecting an intermediate position at which the reference electrical characteristic is subject to a sudden change.

Taking current as an example of the reference electrical characteristic, when the electromagnetic means cause the moving member to move from the extreme closed position to the extreme open position, the sudden change in reference current is representative of a sudden increase occurring in the force opposing movement of the moving member. This increase in the opposing force produced by the spring returning the valve towards the closed position thus tends to oppose displacement of the valve towards the open position and occurs at the moment when the moving member comes into contact with the valve stem. The method of the invention enables this sudden change in the reference current to be associated immediately with an intermediate position of the moving member. Then, knowing the extreme starting position and

said intermediate position of the moving member, it is easy to deduce therefrom a precise value for the timing clearance.

Other characteristics and advantages of the invention appear on reading the following description of a particular and non-limiting embodiment of the invention.

Reference is made to the sole accompanying figure which is a diagrammatic view of an engine valve associated with its actuator device.

The invention is described herein in its application to actuating a valve 1 of an engine given overall reference 2.

The valve 1 possesses a stem 3 which is mounted in a cylinder head 4 of the engine 2 described between a closed position in which the valve is pressed against a seat 5 of the cylinder head 4, and an open position in which the valve is separated from the seat 5 of the cylinder head 4.

Between these two positions, the valve is actuated by means of an actuator given overall reference 6 and mounted on the cylinder head 4 of the engine 2.

The actuator comprises a body 7 having a moving member slidably mounted therein given overall reference 8 and comprising a rod 9 with a first end 10 arranged to bear against a free end of the stem 3 of the valve 1, and a second end 11 secured to an armature 12 received in a housing 13 of the body 7 to slide parallel to the rod 9.

In conventional manner, the body 7 incorporates electromagnetic means for moving the moving member 8.

The electromagnetic means comprise an electromagnet 14 for holding the armature 12 in an extreme closed position of the valve, and an electromagnet 15 for holding the armature 12 in an extreme open position of the valve, which means are open to two opposite faces of the housing 13 of the body 7. In this case, the armature

12 comes into contact with the electromagnet 14 or 15 when it is in the corresponding extreme position.

The electromagnets 14 and 15 are controlled in conventional manner by means (not shown) for servo-controlling them from a reference current and from a travel speed of the moving member 8. This method of servo-control is itself known. Such servo-control can be performed by the engine controller unit which also makes use of a signal representative of the speed of the armature 12 and obtained by taking the derivative of a position signal supplied by a sensor 16 for sensing the position of the rod 9. By way of example, the position sensor 16 may be a conventional Hall effect sensor.

In known manner, the actuator also includes resilient displacement means.

In conventional manner, the resilient displacement means comprise a spring 17 interposed between a face 18 of the body 7 and a shoulder 19 of the rod 9 to urge the armature 12 towards the extreme open position, and a spring interposed between a face 21 of the cylinder head 4 and a shoulder 22 on the valve stem 3 in order to urge the valve 1 into the closed position.

The actuator, the cylinder head 4, and the valve 1 are arranged in such a manner that when the armature 12 is in the extreme closed position and the valve 1 is pressed against its seat 5, there exists clearance j or timing clearance between the first end 10 of the rod 9 and the free end of the valve stem 3.

The method in accordance with the invention enables the clearance j to be determined while the engine is in operation.

The method in accordance with the invention comprises a step of controlling the electromagnets 14, 15 to move the moving member 8 at substantially constant speed from its extreme closed position towards its extreme open position. The travel speed of the moving member can be kept constant as far as the extreme open

position or at least over a distance that is greater than the maximum possible clearance, given the geometrical characteristics of the actuator, of the valve, and of the cylinder head.

Simultaneously, the method includes a step of obtaining reference current values for intermediate positions of the moving member during displacement of the moving member 8 from the extreme closed position to the extreme open position, and a step of determining an intermediate position of the moving member 8 in which the reference current is subjected to a sudden change.

The reference current is supplied by the servo-control means (but it could be measured or detected), and the intermediate positions of the moving member 8 are supplied by the position sensor 16.

The reference current is then associated with the intermediate positions of the moving member 8.

Detecting the intermediate position at which the reference current is subject to a sudden change is preferably performed on the basis of the derivative of the reference current relative to the position of the armature 12. When this derivative is plotted as a curve, the curve presents peaks at the intermediate position corresponding to the point at which the moving member 8 meets the valve stem 3.

Knowing the extreme closed position, the distance between said extreme closed position and the above-mentioned intermediate position can be deduced. This distance corresponds to the clearance j.

Thus, while the moving member 8 is being displaced from its extreme closed position to its extreme open position, the electromagnetic means can be controlled initially to bring the moving member 8 gently up to the above-determined intermediate position so as to put the moving member 8 into contact with the valve stem 3, after which the moving member 8 can be accelerated once it is pressing against the valve stem.

During the displacement of the moving member 8 from the extreme open position to the extreme closed position, the electromagnetic means may be controlled firstly to bring the moving member 8 quickly to the above determined intermediate position in order to have rapid closure of the valve, after which the moving member 8 can be brought gently into the extreme closed position in order to limit contact noise between the armature 12 and the electromagnet 14.

The clearance j is preferably determined periodically, for example once every second.

Naturally, the invention is not limited to the implementation described above, but on the contrary covers any variant in the ambit of the invention as defined by the claims.

In particular, the clearance j can be determined using different modes of operation depending on the speed of the engine and its mode of operation. Thus, since implementation of the above-described method does not interfere with normal operation of the actuator, it does not generate additional noise, and is therefore particularly suited to being used at idling speeds. A method of determining clearance that gives rise to noisier operation of the actuator can be used when the engine is starting or when the engine is running in normal operation mode at a speed greater than some predetermined speed, for example 2000 revolutions per minute (rpm).

In addition, the method of the invention may be implemented for the displacement of a moving member towards the extreme open position as described above, or towards the extreme closed position. Under such circumstances, the travel speed of the moving member is maintained substantially constant, e.g. from a middle intermediate position of the armature.

In addition, the electromagnetic means may be controlled on the basis of some other electrical characteristic, for example a reference voltage.